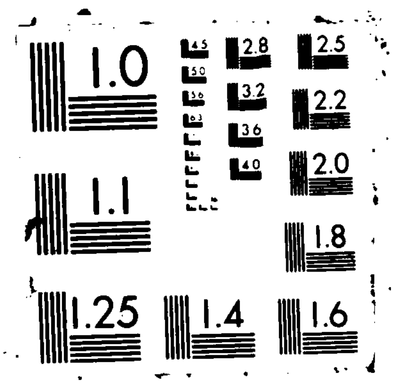
AD-A183 784   COST SAVINGS POSSIBLE WITH AIR FORCE CONVERSION TO JP-8   1/1
AS ITS PRIMARY FUEL(U) AIR FORCE WRIGHT AERONAUTICAL
LABS WRIGHT-PATTERSON AFB OH   C R MARTEL MAY 87

UNCLASSIFIED   AFWAL-TR-87-2037   F/G 5/1   NL

END
9-87
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

DTIC FILE COPY

(2)

AFWAL-TR-87-2037

COST SAVINGS POSSIBLE WITH AIR FORCE CONVERSION TO JP-8 AS ITS PRIMARY FUEL

AD-A183 784

Charles R. Martel
Fuels Branch
Aero Propulsion Laboratory

May 1987

SUMMARY REPORT for Period January 1987 - April 1987

Approved For Public Release; Distribution Unlimited

AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6563

NOTICE

This technical report has been reviewed and is approved for publication.

Charles R. Martel

CHARLES R. MARTEL
Fuels Branch
Fuels and Lubrication Division
Aero Propulsion Laboratory

FOR THE COMMANDER

Robert D. Sherrill

ROBERT D. SHERRILL, Chief
Fuels and Lubrication Division
Aero Propulsion Laboratory

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION	Unclassified
1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
3. DISTRIBUTION / AVAILABILITY OF REPORT	Approved for Public Release; Distribution Unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	AFWAL-TR-87-2037
5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION	Aero Propulsion Laboratory
6b. OFFICE SYMBOL (If applicable)	AFWAL/POSF
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code)	Wright-Patterson AFB OH 45433-6563
7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	Aero Propulsion Laboratory
8b. OFFICE SYMBOL (If applicable)	AFWAL/POSF
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)	Wright-Patterson AFB OH 45433-6563

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO
62203F	3048	05	91

11. TITLE (Include Security Classification)

Cost Savings Possible with AF Conversion to JP-8 as its Primary Fuel

12. PERSONAL AUTHOR(S)

Charles R. Martel

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Summary	FROM Jan 87 TO Apr 87	May 1987	28

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
21	04	
21	05	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

JP-4, JP-8, Jet Fuel, Cost Savings, Safety, USAF Primary Fuel

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

JP-4 has been the primary fuel for the USAF since 1951. However, in 1979 the USAF converted to JP-8 as its primary jet fuel for its operations in Great Britian. Recently, the North Atlantic Treaty Organization (NATO) began the switch from JP-4 (F40) to JP-8 (F34) as its primary jet fuel. However, JP-4 continues to be the primary USAF jet fuel within the continental United States.

The cost and manpower savings possible by converting from JP-4 to JP-8, as the primary jet fuel for the Air Force, are identified and estimated. The much lower volatility of JP-8, as compared to JP-4, accounts for the anticipated savings. For example, aircraft fuel systems must be purged prior to maintenance, and purging aircraft fuel systems that have contained JP-4 can take hours to days. With JP-8 purging may not even be necessary under most ambient temperatures. Another major savings is the reduced evaporation of JP-8, as compared to the more volatile JP-4. Finally, reduced fatalities and casualty losses resulting from ground and flight accidents are estimated.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Charles R. Martel	(513) 255-7431	AFWAL/POSF

DD Form 1473, JUN 86 — Previous editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

PREFACE

This summary report was prepared at the request of Wayne W. Lee, Col USAF, of the Energy Management Branch of the Directorate of Maintenance and Supply, Hq USAF (USAF/LEYSF). A preliminary review of the report findings was presented to the 1987 Energy Management Steering Group on 5 Feb 1987. The author wishes to thank the many contributors to the report, especially those listed as references.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. OBJECTIVE: The purpose of this report is to identify and estimate cost and manpower savings possible if the Air Force switches from JP-4 to JP-8 as its primary jet fuel. This report was prepared at the direction of Hq USAF/LEYSF.

II. BACKGROUND:

1. Jet Fuel Types

JP-1 was the first jet fuel used by the U. S. Army Air Corps starting in 1944. A low freezing point kerosene, JP-1 was an excellent jet fuel but had limited availability, as only a small portion of crude oil could be directly distilled into JP-1. JP-2 was an experimental fuel that never got past the test stage. JP-3 was first used in 1949 but was gradually replaced by JP-4 beginning in 1951. JP-3 was a gasoline-kerosene blend with a Reid vapor pressure between 5.5 and 7.0 psi at 100°F. Although its availability was excellent, its high volatility resulted in excessive boil-off and evaporation losses at high altitudes.

Military specification MIL-F-5624A was first issued in 1951 for JP-4. JP-4 was also a mixture of gasoline and kerosene fractions and had good availability. However, its volatility was less than that of JP-3, with a Reid vapor pressure of 2.0 to 3.0 psi at 100°F.

JP-5 was also developed in the early 1950s for use by the Navy aboard carriers. It has a low volatility with a minimum flash point of 140°F. The vapor pressure of JP-5 is less than 0.1 psi at 100°F; more than a factor of 20 less than that of JP-4. Because of its low volatility and low freeze point, JP-5 has limited availability.

2. Origin of JP-8

During the Southeast Asian conflict the superiority of JP-5 as a fuel for combat aircraft, as compared to JP-4, became evident. Also, statistics of aircraft crashes showed that the probability of post-crash fires with JP-4 fueled aircraft was 83 percent for USAF aircraft. For kerosene fueled Navy and commercial aircraft, the probability of a post-crash fire was 34-35 percent[1]. Based on these data, the Air Force initiated studies to replace JP-4 with a kerosene-based fuel. Commercial Jet A-1, a low-freezing point kerosene fuel used by commercial airlines for trans-oceanic flights and by many overseas airlines, was found to be a suitable fuel, following extensive gunfire tests conducted by the Air Force. Consequently, specification MIL-T-83133, Turbine Fuel,

Aviation, Kerosene Type, Grade JP-8, was prepared and published in 1976. JP-8 is commercial Jet A-1 fuel, but with the addition of fuel system icing inhibitor and corrosion inhibitor/lubricity improver additives. By making JP-8 identical to Jet A-1, except for additives, simplified logistics and reduced production costs are obtained.

For continental United States (CONUS) flights, U.S. commercial airlines use Jet A, which is Jet A-1 but with a higher freeze point. Jet A cannot be used as the primary Air Force fuel because of the danger that it would freeze within aircraft fuel systems in many parts of the world.

3. JP-8 Cost Studies.

Since the early 1970's, several studies have been conducted to identify the problems and costs involved if the Air Force switched to JP-8 as its primary jet fuel. The petroleum industry has stated that such a switch is feasible, but that it would take two or three years to increase the production of kerosene jet fuels to meet the increased demands. Also, there would be a cost penalty associated with the conversion. The most recent of these studies indicated a yearly cost increase of about $300,000,000 for the conversion to JP-8[2]. However, for contracts awarded 1 June 1987, cost differentials between JP-8 and JP-4 were only $0.015/gallon, rising to $0.045/gallon during the heating season. This gives a yearly total cost differential between JP-8 and JP-4 of $55,000,000 to $176,000,000.

Major perturbations have occurred in the petroleum industry in recent years, including the Arab oil embargo of 1973 and the petroleum shortage that occurred in 1979 with the start of the Iran-Iraq war. Within the United States, there has been a significant reduction in motor gasoline demand, because of improved automobile gas mileage, but demands for middle distillates such as commercial jet fuel and diesel fuel have increased. Thus, the American refining industry suddenly finds itself with a surplus of light ends (as used in gasoline and JP-4) and a shortage of middle distillates (diesel fuels and kerosene jet fuels). While these changes in product demand do not make it impossible for the USAF to switch from JP-4 to JP-8, they will likely increase the initial cost penalties.

In 1979 the USAF switched from JP-4 to JP-8 for its operations in Great Britain. NATO has now begun the switch to NATO F-34 (JP-8), and this switch is scheduled to be completed in 1991. The remaining major geographical areas where the Air Force still uses JP-4 are the CONUS and the Pacific Air Forces operations.

4. Comparison of JP-4 and JP-8.

Table I lists important fuel properties of JP-4 and JP-8. As noted above, the primary differences between JP-4 and JP-8 are volatility and density. There is also a significant difference in the volumetric heat of combustion. These property differences, that affect safety, casualty losses, manpower requirements and other cost factors, are discussed in Section III.

TABLE I. COMPARISON OF JP-4 AND JP-8 PROPERTIES

	JP-4	JP-8
Density, kg/m^3	751 - 802	775 - 840
Normal Average (lb/gal)	6.34	6.71
Distillation Range, ^{o}F	50 - 500	300 - 500
Flash-point, ^{o}F, minimum	N/A	100
Reid vapor pressure, psi at 100^{o}F	2.0 - 3.0	N/A
Aromatics, volume %, maximum	25	25
Freeze point, ^{o}F, maximum	-72	-53
Heat of Combustion, Btu/lb, min	18,400	18,400
Normal Average	18,710	18,550
Heat of Combustion, Btu/gallon, Normal Average	118,600	124,500

III. ANTICIPATED SAVINGS

With the help of numerous people in the different operational commands, we have estimated the savings that are anticipated with the proposed conversion from JP-4 to JP-8. Some of these estimates are based on assumed changes in safety procedures possible with JP-8.

1. Fuel Storage and Transport From Refinery to AF Base.

The Defense Fuel Supply Center is responsible for the procurement and distribution of fuels for agencies of the Department of Defense. Fuels are transported from refineries to contractor-owned or government-owned terminals and then to Air Force bases, Army posts, and Navy installations. Fuel transport methods include tank truck, rail car, barge, tanker, and pipeline. Often two or more of these transportation modes are involved in delivering JP-4 from the refinery to the terminal and then to the AF base.

Most terminal storage tanks for JP-4 are equipped with floating roofs or fixed roofs with internal floating pans. The floating roofs and floating pans greatly reduce the evaporation of JP-4,

preventing pollution of the atmosphere and significant fuel losses. However, at the Ozol, California, terminal, there are JP-4 storage tanks that do not have floating roofs or floating pans. To control pollution, this terminal has been fitted with a fuel vapor control system at a cost of about $2,000,000. In addition to recovering the vapors from the bulk tanks, the vapor control system also recovers vapors from truck and rail car fill stands. Note that JP-8, with its much lower vapor pressure, does not require vapor control systems nor storage tanks with floating roofs or floating pans to prevent evaporation.

a. Vapor Control Systems at Terminals.

DFSC has terminals equipped with vapor control systems at Ozol CA, Cincinnati OH, and Norwalk CA. Two other terminals in Florida may soon need vapor control systems to comply with environmental regulations. There are six other DFSC terminals and 22 contractor-owned terminals that may eventually require vapor control systems.

Three types of vapor control systems are available: (a) two-stage refrigeration systems that reliquifies the fuel vapor and returns it to the fuel, (b) absorption systems that uses a chemical absorbent, such as charcoal, to capture the vapors for later return to the fuel, and (c) incinerator systems that burn the vapors. The refrigeration systems are expensive to maintain, and the capture efficiency of the refrigeration systems and absorption systems may not meet the environmental requirements of 95 percent recovery. The incinerator systems do not recover any of the vapors and, in addition, require natural gas or some other fuel to insure the combustion of the vapors. The costs of the vapor control systems have ranged from about $200,000 to $2,000,000, depending on size and system type. Assuming an average cost of $600,000 (the cost of the Cincinnati terminal vapor absorption system), future costs ranging from $1,200,000 (for the two Florida terminals) to $18,000,000 for all DFSC and contractor-owned terminals are projected.

In addition to the initial capital costs, the operating, maintenance and utility costs are estimated to average about $100,000 per year per system, after taking credit for the recovered fuel. For the three existing vapor control systems, the yearly operating cost is about $300,000. If the other 30 DFSC-owned and contractor-owned terminals are eventually equipped with vapor control systems, the yearly operating costs are projected to be an additional $3,000,000.

b. Bulk Storage Tank Maintenance.

Bulk storage tanks must be periodically cleaned and repaired. Prior to entering the tank, all fuel must be removed and the fuel vapors purged to below the 20 percent Lower Explosive Limits (LEL). With JP-4, storage tank purging time requires about 30 percent of the total maintenance manpower[3]. With the low vapor pressure of JP-8, there would be little or no need for purging. The time, manpower and cost savings possible with the reduced purging have not been estimated.

c. Evaporation Losses.

According to Mr William White[4], most JP-4 fuel is transported part of the way to AF bases by tank truck, rail car, barge, or tanker. Each fill/drain cycle results in the venting and loss of fuel vapor when the empty tank is refilled. As noted above, some terminals are equipped with vapor control systems that either recover or incinerate the vapors. The evaporation loss is estimated to be 0.06 percent for each drain/fill cycle (see Appendix A). With a current JP-4 consumption rate of about 3.9 billion gallons per year and with only three of the 33 terminals equipped with vapor recovery systems, one fill/drain cycle results in the loss of about 2,130,000 gallons of fuel worth $1,550,000.

2. Air Force Base Fuel Systems.

a. Ground Fuel System Maintenance

Purging of JP-4 bulk storage tanks is required prior to tank maintenance. The switch to JP-8 would result in savings of about 120 manhours per AF base per year[3]. With over 100 AF bases, these potential savings exceed 12,000 manhours or about 7 manyears. Assuming personnel costs of $67K/year[5], these savings are in excess of $500,000 per year.

b. New Bulk Storage Tank Cost Savings

The Air Force has about 75 bases equipped with the older Panero and Pritchard fuel systems. Because of the age of these systems, their tendency to contaminate fuel with rust particles, and the potential leakage problems with the underground fuel tanks involved, we anticipate that these older systems will be replaced with new fuel systems during the next few years. New Type III fuel systems have already been installed at 10 Air Force bases. However, because of the high vapor pressure of JP-4, the Type III system storage tanks must be equipped with floating pans to

retard evaporation. If JP-8 becomes the primary Air Force fuel, the floating pans in bulk tanks will not be required.

The cost of equipping bulk tanks with floating pans is estimated to be between $25,000 and $50,000 each, depending on size and type. With 75 potential new fuel systems having a minimum of two bulk tanks each, the potential cost advoidance amounts to: $37,500 X 75 X 2 = $5,625,000.

c. Fuel System Vapor Control Systems.

Ten Air Force bases have vapor control systems installed on their JP-4 fuel systems. These systems capture the vapor expelled from underground, 50,000 gallon, ready storage tanks and truck fill stands. The vapor control systems in use include refrigeration, absorption, and incineration systems. At this time there is no immediate requirement to add a vapor control system to any other USAF base fuel system. However, about 75 Pritchard and Panero fuel systems are installed at CONUS USAF bases and additional bases overseas that are potential candidates for JP-4 vapor control systems. The current installed price for an absorption or incinerator vapor control system sized for an Air Force base installation is about $300,000[6]. Thus, the projected cost to retrofit all 75 CONUS bases is about $22,500,000.

Switching all USAF bases to JP-8 would negate the need for vapor control systems, as the vapor pressure of JP-8 is well below the limit of 0.5 psi set by the Environmental Protection Agency for new installations. The switch to JP-8 would also eliminate the operating costs of the existing vapor control systems. Including utilities, maintenance, capital costs, and value of recovered fuel, the current vapor control systems cost between $47,000 and $67,000 per year to operate[6]. To operate the 10 existing vapor control systems costs the Air Force about $500,000 per year. If the other 75 bases are eventually equipped with vapor control systems, their yearly operating costs would be an additional $4,500,000 per year.

d. Reduced Losses Of Fuel By Evaporation

Approximately 800,000 gallons of JP-4 evaporate from storage tanks each year through "standing losses" (see Appendix A). In addition, another 4.6 million gallons of JP-4 are lost through "working losses," i.e., the venting and loss of vapor when a near-empty tank is refilled. The total evaporation losses of JP-4 at AF bases are estimated to be: 0.8 + 4.6 = 5.4 million gallons/year. At the current cost of $0.73/gallon, this loss comes to $3,900,000 per year. If all AF bases are eventually equipped with vapor recovery systems, the "standing losses" (0.8

million gallons) and one of the "working loss" cycles (2.3 million gallons) of JP-4 will be avoided, reducing the yearly evaporation loss to about $1,600,000.

e. Reduced Manpower for Fuel Servicing

(1) One-Fuel Air Force Base. Headquarters TAC[7] provided estimates of potential manpower and equipment savings by converting to JP-8 at TAC bases. As JP-8 can also be used as diesel fuel and heating oil, TAC bases could eliminate the separate fuel storage systems, refueling vehicles, and personnel used to service diesel and heating oils. An estimated 4 manyears and one refueler vehicle per TAC wing could be saved. Also, the expense of maintaining a separate diesel fuel or heating oil bulk storage facility, estimated to be $50,000 per year, would be eliminated. Assuming a total of 15 TAC wings are affected, the potential savings comes to 60 manyears. At $100,000 per manyear[5], the total estimated savings would be: $100,000 X 60 + $50,000 X 15 = $6,750,000 per year. In addition, there would be a one time savings of about $1,000,000 because of the release of 15 refueler vehicles for use elsewhere.

The direct substitution of JP-8 for diesel fuel and heating oil may not be cost-effective in all locations, as JP-8 costs significantly more than diesel fuel and heating oil. However, the amount of diesel and heating oil used amounts to a very small fraction of the jet fuel consumed at most TAC bases. An operational advantage of using JP-8 as diesel fuel is the avoidance of cold-weather operational problems caused by fuel line freeze-up, not uncommon in cold climates with diesel fuels having high cloud points.

Discussions with personnel at Hq SAC and Hq MAC did not identify any potential savings for their bases.

(2) Reduced Number of Refueling Personnel. A minimum of three persons are required for USAF aircraft fueling--a chief servicing supervisor and one person to monitor each fuel nozzle connection and fuel vent[8]. Large cargo and bomber aircraft, which have vents on each wing tip and may use two fuel nozzle connections simultaneously, require up to five servicing personnel. In addition, under concurrent servicing with passengers aboard, a crash/fire/rescue vehicle must be on standby. Other special fueling categories such as cold integrated combat turn-around, hot refueling, and multiple hot refueling, require either a crash/fire/rescue vehicle on standby or other special fire-fighting equipment nearby.

Every day thousands of commercial airlines, with passengers onboard, are routinely and safely refueled with Jet A or Jet A-1, concurrently with baggage loading, food loading, and occasionally minor maintenance. In addition, other aircraft enter and leave gates located only a few feet away. Yet only the refueler operator is involved with the fueling operation. With JP-8, which has the same flammability characteristics as Jet A and Jet A-1, the Air Force could reduce the number of refueling personnel to one, or at the most, two. This would be a reduction of one or more. In addition, the requirements for standby crash/fire/rescue vehicles and fire extinguishers could be relaxed.

Table 2 lists the estimated numbers of refueling operations per year for most USAF aircraft. The number of refuelings and the refueling times are estimated, assuming about 40 minutes refueling time for the smaller fighter/attack type aircraft and up to 1-1/2 hours for the largest bomber and cargo aircraft. These refueling times include travel and hook-up times.

TABLE 2

ESTIMATED NUMBER OF FUEL SERVICING OPERATIONS FOR 1985

A/C TYPE	FLIGHT HRS PER YEAR	EST. SORTIE LENGTH, HRS	REFUELINGS PER YEAR	EST REFUELING TIME/YR (HRS)
A-7D	74800	1.5	49867	33261
A-10	221800	1.5	147867	98627
F-4	342600	1.5	228400	152343
F-15	182900	1.6	114313	114313
F-16	203600	1.6	127250	84876
F-106	23600	1.3	18154	12109
F-111	80600	3	26867	26867
C-130	361100	4	90275	117358
C-141	289800	4.1	70683	98956
C-5A	59300	4.1	14463	21695
KC-135	400000	4.1	97561	136585
B-52	104000	6.8	15294	22941
		TOTALS	1000993	919930

(Aircraft not listed include the KC-10, T-37, T-38, and C-21)

As seen in Table 2, over 900,000 hours are spent per year in refueling USAF aircraft. With a minimum of three refueling personnel required, the total manhours exceeds 2,700,000 or 313 manyears per year. Reducing the number of refueling personnel from greater than three to a maximum of two would save in excess of 104 manyears per year. As each manyear costs the Air Force

about $100,000[5], the potential savings with JP-8 would exceed $10,400,000 each year.

An additional manpower reduction possible with JP-8 occurs during in-shelter, closed-door refueling. When refueling aircraft with JP-4 within enclosed shelters, refueling personnel are limited to four refuelings per duty cycle with at least 60 minutes of low or no fuel vapor exposure between refuelings[8]. With JP-8 there are no such limits.

f. Reduction in Fuel Related Fires and Explosions.

We anticipate that the use of JP-8 will prevent the destruction of an estimated $1,000,000 of ground fuel facilities explosions each year, based on recent accident data[9].

3. Aircraft In-Flight Savings.

a. Combat Losses. An analysis of aircraft losses in a combat environment was conducted in 1974 for USAF and Marine aircraft using JP-4 and Navy aircraft using JP-5[1]. This analysis was flawed, as the aircraft loss information was often incomplete and direct comparisons could be misleading. For example, Navy, Marine, and Air Force aircraft tended to operate under different combat environments. Nevertheless, for F-4 type aircraft using JP-5 fuel, only about 50% of the losses involved fires or explosions. For Marine and USAF F-4 aircraft using JP-4 fuel, about 56% of the combat losses involved fires or explosions. While this difference was not statistically significant, the trend was toward fewer fires and explosions with JP-5.

Another part of the analysis compared the relative number of fires and explosions when external aircraft fuel tanks were hit by gunfire larger than 7.62mm. Only 3 percent of the gunfire hits on external aircraft fuel tanks containing JP-5 resulted in fires and explosions. For tanks containing JP-4, over 16 percent of the gunfire hits resulted in fires or explosions.

b. Peacetime Aircraft Losses. Information obtained from the Air Force Inspection and Safety Center[9] indicated that about one USAF aircraft is lost each year under circumstances that indicate the loss would not have occurred if JP-8 had been used rather than JP-4. Examples of these fire and explosion losses include: F-4 lost during hot pit refueling, F-4 and C-130 losses due to in-flight explosions caused by lightning strikes, C-5A loss due to a lightning strike-initiated explosion while on the ground, two B-52 losses due to fuel tank explosions, a KC-135 lost during ground fuel transfer, and F-4 and C-5A losses during maintenance operations. The average annual dollar lost through these fuel-

related accidents is estimated to be $12,000,000, based on value of the destroyed or damaged aircraft. Note that new replacement aircraft may cost three or four times this value. Already in 1987 a KC-135 has been destroyed and a T-38 severely damaged by in-flight fires that probably would not have occurred if JP-8 had been in use.

c. Aircrew Fatalities. Records maintained by the Air Force Inspection and Safety Center indicate that about 80 crewmembers are killed each year in USAF aircraft crashes. Figure 1 shows USAF aicraft accident fatalities for the past ten years.

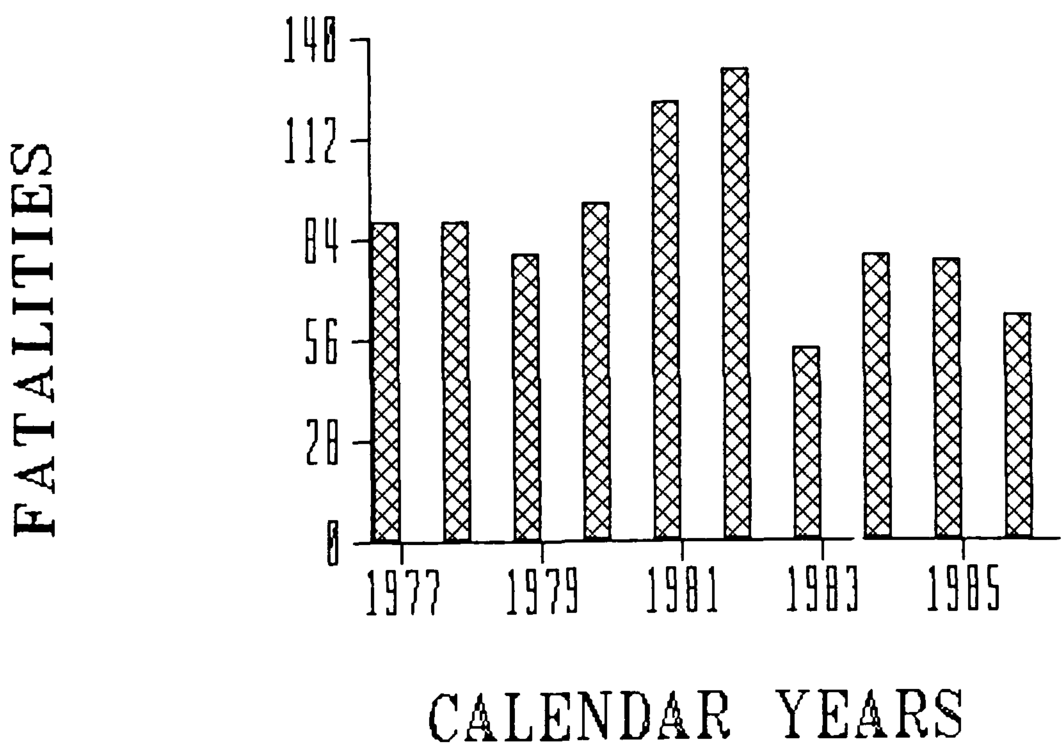


FIGURE 1. USAF AIRCRAFT ACCIDENT FATALITIES

Accident statistics obtained in an earlier study[10] are shown in Table 3. These statistics indicate that the probabilities of surviving a crash are 0.76 for JP-8/Jet A kerosine fuels and 0.63 for JP-4/Jet B wide-cut fuels. Using these probabilities, the estimated annual USAF crewmember fatalities would be cut from 80 to 51 with the switch to JP-8. As the cost per crewmember fatality is estimated to be about $350,000, a yearly savings of about $10,100,000 would be expected.

TABLE 3. ACCIDENT STATISTICS

	JP-8/JET A	JP-4/JET B
PROBABABILITY OF SURVIVING ACCIDENT WHEN FIRE OCCURS		
LANDING	0.88	0.85
TAKE-OFF	0.29	0.25
APPROACH	0.27	0.23
PROBABILITY OF FIRE AFTER A/C CRASH (207 ACCIDENTS)	0.66	0.73
PROB. OF SURVIVING CRASH (207)	0.76	0.63
PROB. SURV. IN-FLIGHT FIRE (13)	0.83	0.50
GROUND AIRCRAFT ACCIDENTS (13)	4 A/C MOD. DAMAGE	7 DESTROYED 2 MINOR DAM.

d. Evaporation/Boil-off Losses.

During aircraft flight, warm fuel is rapidly transported to high altitudes where the reduced atmospheric pressure greatly accelerates fuel evaporation. (With gasoline, boiling of the fuel may occur under some conditions.) Dissolved air in the fuel also comes out of solution and contributes to the venting of fuel vapor. This estimated loss for JP-4 in USAF aircraft is about 28 million gallons/year, and constitutes a significant air pollution source. At a cost of $0.73 per gallon, this loss amounts to $20,400,000 per year.

4. Reduced Aircraft Maintenance Costs

a. Fuel System Purging At Air Logistic Centers

Prior to moving aircraft into hangers for depot maintenance, all fuel tanks are drained and the concentration of fuel vapors within the tanks are reduced to below 20 percent of the Lower Explosive Limit (LEL). With JP-4 this requires that after the tanks have been drained, either a liquid purging fluid must be pumped into the aircraft fuel system and drained (to remove JP-4 residues and vapors) or the fuel system must be purged with air until the 20 percent LEL is obtained.

San Antonio, Ogden, and Warner Robbins Air Logistics Centers (ALCs) use MIL-F-38299 purging fluid (a high flash-point kerosene) for this purpose. This requires the procurement,

storage, handling, and reclamation or disposal of the purging fluid. The other two ALCs use JP-5. JP-5 can be reused two to four times before it is downgraded to JP-4, at a value loss of about $0.06/gallon.

The conversion of AF bases to JP-8 would eliminate most fuel system purging operations. The MIL-F-38299 purging fluid or the JP-5 and its supply, storage, handling, and reclamation system would no longer be needed. As seen in Table 4, the elimination of a separate purging fluid and its system operation and maintenance (O & M) costs will result in savings of about approximately $250,000 + $180,000 = $430,000 per year. Table 4 also shows the estimated manpower required to maintain the purge fluid systems to be 7.8 manyears at a cost of $523,000 per year. The total estimated savings with the elimination of a separate purging fluid comes to about $900,000 per year.

The estimated manpower required to purge aircraft prior to depot maintenance is 40.5 manyears[11]. (See Table 5.). As the labor cost per manyear is about $67,000[5], we estimate the manpower costs for aircraft purging at the Air Logistic Centers will be 40 X $67,000 = $2,680,000.

TABLE 4. AIRCRAFT PURGING SYSTEMS COSTS AT AIR LOGISTICS CENTERS

ALC	PURGE FLUID	SYSTEM O&M MANYEARS	ESTIMATED COSTS ($1000) PURGE FLUID	O & M	MAN POWER	TOTAL
SA-ALC	MIL-F-38299	1.7	58	50	114	220
SM-ALC	JP-5	1.7	54	30	114	196
WR-ALC	MIL-F-38299	1.7	73	50	114	235
OC-ALC	JP-5	1.7	60	30	114	202
OG-ALC	MIL-F-38299	1	5	20	67	92
	TOTALS	7.8	250	180	523	945

Table 5 also shows that the downtime for aircraft undergoing purging comes to about 1.25 years; i.e., about 1.25 aircraft are unavailable for use because of purging prior to maintenance.

TABLE 5. AIRCRAFT PURGING OPERATIONS AT AIR LOGISTICS CENTERS

ALC	A/C TYPE	NO. A/C PER YEAR	MH PER PURGE	TOTAL MH	A/C DOWN TIME HRS	TOTAL DOWN TIME HRS
SA-ALC	B-52	27	192	5184	16	432
	C-130	40	48	1920	8	320
	C-5A	17	153	2601	16	272
SM-ALC	A-10	360	21	7560	5	2100
	F-111	290	17	4930	4	1160
	F-4	100	17	1700	4	400
OC-ALC	E-3	19	178	3382	16	304
	KC-135	64	52	3328	8	512
	B-52	34	180	6120	16	544
	A-7	96	30	2880	8	768
			TOTALS	39605 = 22.5 MY		6812 = 0.79 YRS

WR-ALC AIRCRAFT PURGING PERSONNEL = 14 ESTIMATE 0.26 YRS
OC-ALC ASSUME A/C PURGING PERSONNEL = 4 ESTIMATE 0.2 YRS

TOTAL MY = 40.5 TOTAL YRS = 1.25

b. Fuel System Purging at Operational Air Force Bases.

Operational bases normally use air to purge aircraft fuel systems, as liquid purging fluids are unavailable. This requires the use of blowers and suction devices to flow air through the aircraft fuel tanks. Three persons and 30-45 minutes are required to purge an aircraft fuel tank prior to maintenance[12]. With JP-8 this purging would not be required at most bases, as the 20 percent LEL for JP-8 will be exceeded only when the JP-8 fuel is above about 75°F. Even if air purging is required for a system that contained JP-8, the length of the purging operation will be only a fraction of that required for JP-4. The time required to purge fuel tanks that had contained JP-4 was estimated to be 4 percent of the total time required for fuel tank repair.

In 1985 the Air Force spent over 430,000 maintenance manhours to repair aircraft fuel tanks (Table 6)[13]. Assuming 4 percent of this time was spent in purging the aircraft fuel systems prior to maintenance, about 10 manyears of effort was involved. For a cost of $100K/manyear, the total estimated cost to the Air Force was about $1,000,000 per year.

TABLE 6. AIRCRAFT FUEL TANK REPAIRS FOR 1985

AIRCRAFT TYPE	FLIGHT HOURS PER YEAR	MAINTENANCE ACTIONS	MAINTENANCE MANHOURS
A-7D	74,800	1,046	23,385
A-10	221,800	1,263	23,385
F-4	342,600	9,137	111,131
F-15	182,900	4,759	61,926
F-16	203,600	2,647	37,168
F-106	23,600	125	690
F-111	80,600	1,848	21,947
C-130	361,100	4,211	63,538
C-141	289,800	7,517	56,486
C-5A	59,300	878	7,179
B-52	104,000	1,798	24,283
TOTALS	1,944,100	35,224	431,118

NOTE: AIRCRAFT NOT INCLUDED: KC-135, KC10, T-37, & T-38

In some specific maintenance situations aircraft must be defueled prior to hangering. With the replacement of JP-4 with JP-8, possibly additional manpower and time could be saved by not defueling the aircraft prior to hanger maintenance (except when repair to the fuel system is required).

c. Reduced Aircraft Fuel System Leaks. An Air National Guard squadron of F-15A aircraft operating from a Navy installation near New Orleans, LA, has experienced excessive fuel system leak problems. These leaks occur when the fuel tank groove sealant and "O" ring seals swell in the presence of JP-4 (received from other AF bases) and then shrink when exposed to JP-5 (received from the Navy installation). Considerable expense has been involved in trying to correct this sealant shrink/swell problem, both at the operational level and in on-going R&D to develop improved sealants and elastomers. The shrink/swell fuel system leak problem is not unique to F-15A aircraft and has been a continuing problem with other aircraft[14]. The conversion from JP-4 to JP-8 throughout the Air Force would greatly reduce this problem, as only minor swelling/shrinkage occurs with different batches of JP-8 and JP-5 fuels. It is conservatively estimated that 10 percent of USAF aircraft fuel system leaks are caused by this shrink/swell behavior, at an estimated annual cost of 24 manyears and a cost of $2,400,000.

d. Reduced Cost of Fuel System Maintenance Equipment. Safety requirements for special equipment used to inspect and

repair aircraft fuel systems are becoming increasingly stringent. The costs for non-destructive inspection devices, radios, hazardous vapor detectors, inspection lights, and other equipment used to repair aircraft fuel systems is greatly increased by the requirements that these items be intrinsically-safe or explosion-proof. With the greatly reduced fire hazards of JP-8, these requirements could be relaxed.

5. Avoided Expenses

a. Reduced Aircraft Downtime.

Table 6 shows that USAF aircraft undergo over 35,000 fuel system maintenance actions requiring in excess of 430,000 maintenance manhours each year. Assuming that every maintenance action requires fuel tank purging prior to the maintenance action and that each fuel tank purge requires 30 to 45 minutes, over 27,000 hours of purging occurs. (We believe this time is conservative, as aircraft whose fuel tanks contain the open-pore foam for explosion protection can take hours to purge.) This equals three years of aircraft downtime each year for fuel system purging. With the elimination or greatly reduced purging possible with JP-8, the Air Force can purchase fewer aircraft and still maintain the same level of effectiveness.

The anticipated reduction in aircraft fuel system leaks was conservatively estimated to reduce fuel system repair by 10 percent. This estimated reduction would be about 41,000 manhours per year. Assuming two to three maintenance personnel working together, this would result in aircraft downtime of 41,000/2.5 = 16400 hrs or about two years of aircraft downtime for fuel system leak repair that would be avoided by the change to JP-8.

As recorded in Table 5, an additional 1.25 aircraft downtime years is estimated for aircraft undergoing purging at the Air Logistic Centers. The total anticipated reductions in aircraft downtime is: 3 + 2 + 1.25 = 6.25 aircraft years/year. Assuming an average aircraft life of 18 years and an average cost of $25,000,000, this 6.25 years of aircraft downtime costs the Air Force about $8,700,000 per year. We believe this estimate is conservative, as many other maintenance actions presently require fuel system purging, and most new aircraft cost more than $25,000,000.

b. Reduced Fuel Purchases

Jet fuel is presently bought by the gallon or barrel, i.e., on a volumetric basis. However, the significantly greater density of JP-8, as compared to JP-4, results in a gallon of JP-8 containing

about 5 percent more energy than a gallon of JP-4 (Table I). About 70 percent of this increased energy density can be translated into increased range or flight time. Thus, for the same number of flying hours the USAF could reduce its purchase of jet fuel by about 3.5 percent per year. At the present price of $0.73 gallon for JP-4 and a yearly purchase of 3.9 billion gallons of jet fuel, we anticipate a savings of 137 million gallons of fuel at a cost of $100,000,000 per year.

IV. OTHER FACTORS FAVORING SWITCH TO JP-8

The reasons for the Air Force to switch to JP-8 are even stronger today than in the 1970s. For example, the USAF is developing new, supersonic cruise aircraft. The elevated temperatures associated with sustained supersonic cruise will cause significant losses of the volatile JP-4 fuel during flight. Greatly increased vulnerability of these advanced aircraft to fires and explosions will occur when using JP-4, as compared to JP-8. For example, the higher volatility of JP-4 will increase fuel transfer and pumping problems during high-altitude and high-temperature (high-Mach) flight. If a fuel tank boost pump fails, the high vapor pressure of the JP-4 will prevent the use of the engine fuel pump to suck the fuel from the tank to the engine. Either a spare boost pump or pressurized fuel tanks would be required. Pressurized fuel tanks increase the fire and explosion hazards, when damaged by enemy action or during crash landings.

The use of protective shelters to house aircraft also favors the use of JP-8 over JP-4. The volatility of JP-4 increases the dangers of fires and explosions during refueling operations or should a fuel spill occur. In addition, the marked reduction of fuel fumes within enclosed shelters would help to protect the health of personnel within the shelters.

V. SUMMARY OF POTENTIAL SAVINGS

Based on the reduced vapor pressure and increased volumetric heat energy of JP-8, as compared to JP-4, significant monetary and manpower savings can be realized with the switch from JP-4 to JP-8 for USAF operations. Tables 7 and 8, below, summarize these estimated savings.

TABLE 7. SUMMARY OF MANPOWER SAVINGS

AFB FUEL SYSTEM OPERATIONS	
BULK TANK MAINTENANCE	7 MY
ONE FUEL AFB	60 MY
REDUCED REFUELING PERSONNEL	104 MY
REDUCED AIRCRAFT MAINTENANCE COSTS	
ALC PURGE SYSTEM O & M	8 MY
ALC PURGING OPERATIONS	40 MY
FIELD PURG. OPERATIONS	10 MY
REDUCED FUEL SYSTEM LEAKS	24 MY
TOTAL MANPOWER SAVINGS	253 MY

TABLE 8. SUMMARY OF ESTIMATED YEARLY COST SAVINGS

DFSC TERMINALS	
VAPOR CONTROL SYS. OPERATION	$ 0.3 M
REDUCED EVAPORATION LOSSES	$ 1.6 M
AFB FUEL SYSTEM OPERATIONS	
GROUND FUEL SYS. MAINTENANCE	$ 0.5 M
FUEL VAPOR CONTROL SYS OPERATION	$ 0.5 M
REDUCED EVAPORATION LOSSES	$ 3.9 M
ONE-FUEL BASE	$ 6.8 M
REDUCED REFUELING PERSONNEL	$ 10.4 M
REDUCED FIRES & EXPLOSIONS	$ 1.0 M
AIRCRAFT IN-FLIGHT SAVINGS	
REDUCED AIRCRAFT LOSSES	$ 12.0 M
REDUCED AIRCREW FATALITIES	$ 10.1 M
REDUCED EVAPORATION LOSSES	$ 20.4 M
REDUCED AIRCRAFT MAINTENANCE COSTS	
ALC PURGE SYSTEMS	$ 1.0 M
ALC PURGING OPERATIONS	$ 2.7 M
FIELD PURGING OPERATIONS	$ 1.0 M
REDUCED FUEL SYSTEM LEAKS	$ 2.4 M
AVOIDED EXPENSES	
AIRCRAFT DOWNTIME	$ 8.7 M
REDUCED FUEL PURCHASES	$ 100.0 M
TOTALS	$ 183.3 M

Table 9 lists additional projected costs that will be avoided with the Air Force conversion from JP-4 to JP-8.

TABLE 9. WORST-CASE ADDITIONAL COST SAVINGS

VAPOR CONTROL SYSTEMS FOR EIGHT DFSC AND 22 CONTRACTOR-OWNED TERMINALS - ONE TIME COST*	$ 18,000,000
FLOATING PANS FOR NEW BULK STORAGE TANKS AT 75 AIR FORCE BASES	$ 5,625,000
VAPOR RECOVERY SYSTEMS FOR 75 MORE AF BASES - ONE TIME COST*,**	$ 22,500,000
TOTAL ADD'L SAVINGS	$ 45,125,000

*RECOVERED JET FUEL VALUE IS ABOUT EQUAL TO OPERATING COSTS OF VAPOR RECOVERY SYSTEMS.

** VAPOR CONTROL SYSTEM WOULD STILL BE NEEDED FOR TRUCK FILL STANDS EVEN IF STORAGE TANKS HAVE FLOATING PANS.

REFERENCES

1. AFAPL-TR-74-71, "Assessment of JP-8 as a Replacement Fuel for the Air Force Standard Jet Fuel JP-4, Parts I and II," June 1975.

2. AGARD Advisory Report No. 227, "Propulsion and Energetics Panel Working Group 16 on Producibility and Cost Studies of Aviation Kerosines," July 1985.

3. Information obtained from Mr. Patrick Mumme, AFESC/DEMM, Tyndall AFB FL, AV 970-6357.

4. Information obtained from Mr William White, Defense Fuels Supply Center (DFSC-F), Cameron Station, Alexandria VA, AV 284-7170.

5. AFLCP 173-10, "AFLC Cost and Planning Factors."

6. R. M. Schilling and C. S. Daw, "McClellan Air Force Base, California, JP-4 Fuel Storage and Transfer Facilities Vapor Control Feasiblity Study," Draft Report dated September 1986.

7. Information obtained from Mr Cliff Heath, HQ TAC, Langley AFB VA, AV 574-2057.

8. Technical Order 00-25-172, "Ground Servicing of Aircraft and Static Grounding/Bonding," Paragraph 5-40.

9. Information obtained from Mr Gregory Gandee, AFISC/SESO, Norton AFB CA, AV 876-6844.

10. "Aircraft Kerosine Versus Wide-Cut Fuel-Safety Considerations," SAE 760527, May 1976.

11. Information obtained from Ms. Karen Solari, SA-ALC/MAQCE, Kelly AFB TX, AV 945-3100, and Mr Dewey Meadows, WR-ALC, Robbins AFB GA, AV 468-4340.

12. Information obtained from Mr Sloan, 4950th FMS/MAFSF, Wright-Patterson AFB OH, AV 787-4070.

13. Information supplied by Capt Juan Hurato, AFALD/ERE, Wright-Patterson AFB OH, AV 785-3682.

14. SA-ALC/MM-8149, "Fuel System O-Ring Leaks on Post P.D.M. C-5A Aircraft," C. J. Forzono, September 1983.

APPENDIX A

LOSS OF JP-4 BY EVAPORATION

Two loss modes occur with volatile liquids in bulk tanks: (1) standing losses and (2) working loss (i.e., the fuel vapor expelled during a drain/fill cycle). Nelson[1] estimates a standing loss of 5% per year for gasoline with a Reid vapor pressure of 10 psi stored in a 5,000-Bbl above-ground storage tank at 60°F. For a crude oil with a Reid vapor pressure of 2 psi, the loss is 33 percent that of the gasoline; i.e., 1.67 percent. This value of 1.67 percent loss per year was assumed for JP-4, as it has a Reid vapor pressure of between 2 and 3 psi.

For a standing loss rate of 1.67 percent per year, the fuel loss for refueler vehicles and the 50,000-gallon underground ready tanks (used in the Pritchard and Panero fuel systems found at most CONUS Air Force bases) is estimated at 800,000 gallons per year, based on 75 Air Force bases each equipped with 12 each, 50,000 gallon underground tanks and 100 Air Force bases each equipped with six each 5,000 gallon refuelers. Bulk storage tanks with floating roofs or floating pans have very little evaporation losses and are therefore not considered.

Working losses occur when fuel vapors are vented as a near-empty tank is refilled. Nelson[1] estimates the fill/drain working loss to be 0.2 percent for a 10-psi Reid vapor gasoline. For a 2-psi Reid vapor pressure crude oil the value is 33 percent of that of the gasoline or about 0.067 percent for each fill/drain. Schilling and Daw assume a loss rate of 0.06 percent[2]. Using the more conservative value of 0.06 percent and assuming 3.9 billions of JP-4 per year, each fill/drain cycle results in the loss 2,300,000 gallons of JP-4 per year. JP-4 normally undergos three fill/drain cycles; viz., at the bulk storage tanks, at the 50,000-gallon underground tanks, and at the using aircraft. However, most bulk storage tanks have floating pans or floating roofs which eliminate most of the evaporation loss, so there are only two fill/drain cycles of concern. With each fill/drain cycle resulting in a loss of 2.3 million/gallons/year, the total loss is assumed to be 4.6 million gallons/year.

Fuel loss during aircraft flight is the third mode that must be considered. Smith[3] documents losses of 2 percent for JP-4 fuel with an initial temperature of 40°C (104 °F) and flight at an altitude of 40,000 ft. Initial fuel temperatures are estimated to be 60°F, much lower than 104°F. Assuming the evaporation loss is directly proportional to vapor pressure, the loss of JP-4 during flight is estimated to be 0.8 percent. For an annual

consumption of 3.5 billion gallons of JP-4 per year, this loss comes to 28 million gallons/year.

The sum of these estimated losses of JP-4 by evaporation is: 0.8 + 4.6 + 28 = 33.4 million gallons per year. At the current price of JP-4 of $0.73/gallon, this loss comes to about $24,000,000/year.

[1] W. L. Nelson, "Petroleum Refinery Engineering," pages 271-275, Fourth Edition, McGraw-Hill Book Company.

[2] R. M. Schilling and C. S. Daw, "McClellan Air Force Base, California, JP-4 Fuel Storage and Transfer Facilities Vapor Control Feasibility Study," Draft Report dated September 1986.

[3] Maxwell Smith, "Aviation Fuels," pages 256-259, G. T. Foulis & Co., Ltd.

U.S. Government Printing Office 1987

END
9-87
DTIC